Attachment 1

Storm Resiliency Program Analysis and Acceleration Proposal

Storm Resiliency Program Analysis and Acceleration Proposal

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1. Storm Resiliency Program Overview

In 2012, Unitil embarked on a pilot study to test the effectiveness of performing targeted vegetation management to reduce effects of storm events on the electric system. This is known as the Storm Resiliency Program (SRP) today. This pilot was initiated after the Unitil Service territory in New Hampshire was met with 2 large events in 2011, Hurricane Irene and the October Snowstorm and had sustained other frequent major storm events over the past 4 years.

The 2011 October Snowstorm caused widespread damage and prolonged outages and was ranked as the 3rd largest event in the state's history[7] at the time. The Commission's Regulated Utilities' Preparation and Response Report indicated customers expressed frustration with costs incurred with the outages.

> *"Customers also expressed frustration with the personal costs incurred as a result of multi-day outages. For residential customers, those costs are driven in part by the purchase of fuel for generators; lodging and meals for those who cannot remain in their homes; lost wages for those who work from home; and spoiled food with the loss of refrigeration. Business customers experienced revenue losses, as well. Without electricity, many customers in New Hampshire lack water, as well as heat."*[8]

In after-storm meetings with towns and annual emergency preparedness meetings, Unitil also saw that customers expressed a desire for something to be done. Customer's increased reliance on technology coupled with the economic cost of service interruption and safety aspect contributes to the changing expectation of uninterrupted service. Certain towns even expressed support for more tree work to be done.

The Company designed a plan to perform vegetation management activities on appropriate circuits and critical sections of these circuits over a ten year time period. The design was for critical 3-phase sections of a selected circuit, from the substation out to the first protection device, to have tree exposure reduced by removing all overhanging vegetation or pruning "ground to sky." Intensive hazard tree review and removal was conducted on these critical sections. In cases where the customer count was over 500 customers at the first protection device, overhang and hazard tree removal was continued to the second protection device. From that point, hazard tree inspection and removal was conducted out to the third protection device or along remaining three phase lines.

[7] NH PUC "The October Snowstorm – New Hampshire's Regulated Utilities' Preparation and Response" November 20,2012, Appendix E p55
[8] NH PUC "The October Snowstorm – New Hampshire's Regulated Utilities' Preparation and Response" November 20,2012, Section VI p38

The SRP work has the ability to prevent tree related failures and subsequent electric incidents. This reduction in incidents reduces damage to the electric infrastructure and the need for crews to respond, reducing overall storm costs.

However, tThere are also a number of additional benefits associated with a tree exposure reducing Storm Hardening program, including:

- Preserving municipal critical infrastructure
- Minimizing the dependence on mutual aid and off system resources
- Minimizing the total number of resources required to restore service
- Shortening the duration of major events
- Minimizing the overall cost of restoration
- Reducing economic loss to municipalities, businesses, and customers
- Most cost effective solution vs. other alternatives
- Minimal bill impact on a per-customer basis

The Company believes that reliable electric service is essential to the economic well-being of the businesses and industries we serve, and to the welfare of those who live and work in our communities. Interruptions to electric service are both expensive to repair, and expensive to the businesses and individuals who rely on electricity for commercial and household purposes. To cite one example, a 2004 study conducted by Lawrence Berkeley National Laboratory (Berkeley Lab) (funded by the Office of Electricity Delivery and Energy Reliability of the U.S. Department of Energy) estimated that electric power outages and blackouts cost the nation about $80 billion annually. Of this, $57 billion (73 percent) was attributed to losses in the commercial sector and $20 billion (25 percent) in the industrial sector.[9] In subsequent studies performed by Berkeley Lab in 2009 and 2015 provided extensive data on the cost of customer interruptions, including estimates of the average cost of electric interruptions (in 2008 and 2013 dollars respectively) broken down by customer type, outage duration, time of day, day of week, and other variables.[10]

To test the validity of the program as designed, a pilot of the program was implemented in 2012 and 2013 which was met with positive results, acceptance, and praise from customers[11]. With the Commission's support, in 2014 the storm resiliency pilot program became a full Storm Resiliency

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[9] Understanding the Cost of Power Interruptions to U.S. Electricity Consumers, Kristina Hamachi LaCommare and Joseph H. Eto, September 2004.

[10] Estimated Value of Service Reliability for Electric Utility Customers in the United States, Michael J. Sullivan, Ph.D., et al, June 2009.
Updated Value of Service Reliability Estimates for Electric Utility Customer in the United States, Michael J. Sullivan, Ph.D., et al, January 2015.

[11] Unitil "2013 Storm Resiliency Pilot Program Results – Addendum to the: Storm Resiliency Pilot Program 2012 Cost Benefit Analysis" January 24, 2014

Program, occurring in tandem with the vegetation management program. Including the pilot years, six years of storm resiliency work have been implemented to date.

2. Storm Resiliency Program Analysis

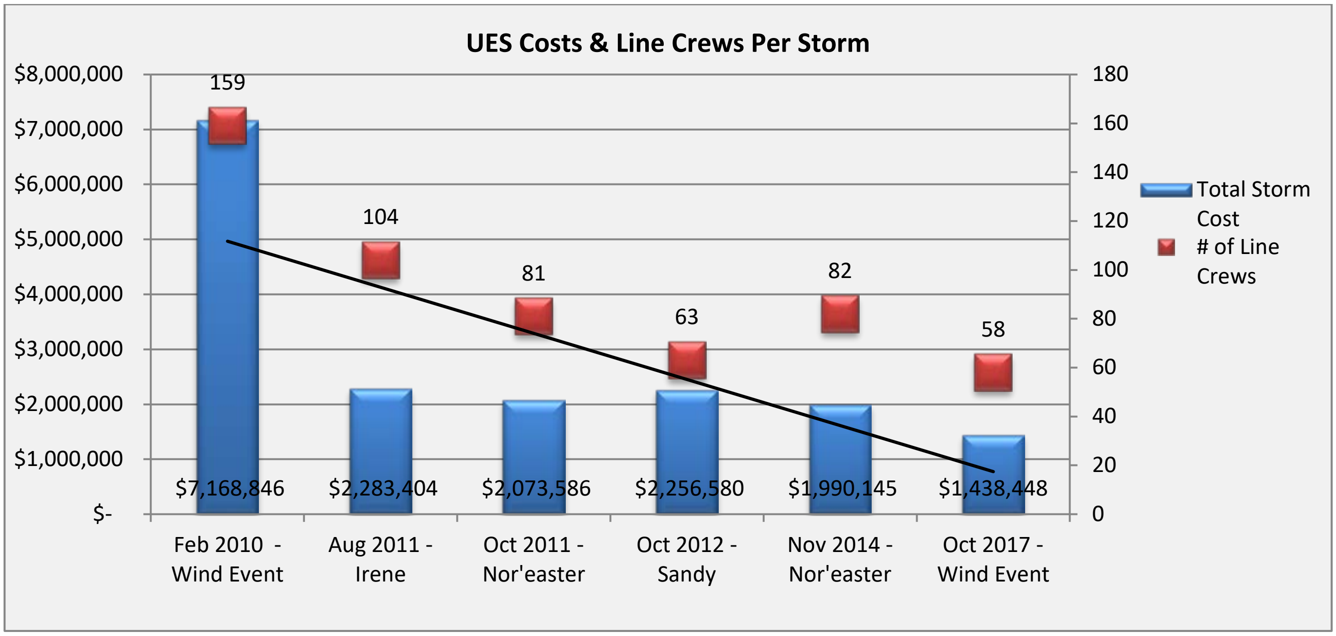
The SRP's objective is to enhance the reliability of electric feeders out to the first protective device to support the concept of bringing "normalcy" back to the community as soon as possible after a storm event. It is the realization of this concept that we would like to explore further.

As an initial matter, it's difficult to prove what might have happened had the Company not undertaken the SRP. However, by trending storm data over the past several years, there is sufficient empirical evidence to conclude that the program is meeting its stated objectives. Those objectives include:

- Improve the reliability of treated circuits out to the first protected device
- Reduce the cost of storms
  - Shorten restoration time
  - Fewer resources needed to restore
- Enhance customer relations by improving power availability during events that previously caused power interruptions

Company has reviewed the biggest storm events to impact New Hampshire over the past 7 years (see Chart 1). The data shows a decline in resources needed and thereby a decline in the overall cost of the restoration. The Company is of the opinion that there is a break point as how fast restoration can occur after the onset of an event, given the activities that have to be performed prior and during restoration such as the public safety phase. The Company believes, however, that restoration times in general have been reduced by approximately 1-2 days such that the type of storms that would have formerly taken 5-6 days to recover from are now are being restored in 4-5 days. The key is that we can now restore with fewer resources as a result of fewer damage locations related to trees, a direct result of the SRP.

Chart 1



In addition to the cost and resource trends in major storms, there is evidence of decline in outages under normal conditions and as a result of minor storms. This can be seen by studying the sections of circuit where the SRP has been performed. The Company compared Pre-SRP (year SRP performed and previous 4 years) and Post-SRP (years after SRP – varies from 5 to 1 depending on the circuit) "tree related" outages on all SRP circuit sections. The areas where SRP ground-to-sky and intensive hazard tree removal were completed had a 74% reduction in tree related outages per year, and a 99.9% reduction in outages per mile per year.[12] See Table 1 below. There were only 15 outages on Post-SRP areas compared to 554 tree-related events in this time period. Outages on the ground-to-sky portions of SRP circuits Post-SRP accounted for only 2.7% of the tree related outages on the SRP circuit over the same time period, versus 7.5% (152 of 2,031) tree related outages for the five years prior to the SRP being performed.

Table 1

Areas of Ground to Sky – Not Including "Major Events"

	PRE-SRP	POST-SRP	% Reduction
Outages Per Circuit Per Year	1.23	0.32	74%
Outages Per Mile Per Year	0.3107	0.0002	99.9%
Average Customer Minutes of Interruption per year	1,795,684	669,883	63%
Average Customer Minutes of Interruption per year per mile	368,527	108,819	71%

[12] Excluding major events and sub-transmission data

In major events, the reduction in outages is not quite as pronounced, due to the lack of data being collected during storm events, and lack of opportunity to collect the data. Without data showing locations of tree-related trouble, an outage affecting a large amount of customers Pre-SRP could be related to numerous cases of tree damage, and that same outage Post-SRP could be related to only one case of tree damage. However, both events appear as a similar, single outage on the circuit. Setting aside discrepancies in the outage data, attempting to compare Pre-SRP major events and Post-SRP major events is difficult due to the fact that in many of the events, individual outage data (or even circuit level data) is not available. The February 25, 2010 wind storm, August 28, 2011 Hurricane Irene, October 31, 2011 Nor'easter, and October 29, 2012 Sandy do not have outage data for comparison. In these events it was not feasible to collect individual outage data. Perhaps the ability to be able to collect circuit and outage level data in recent major events, such as the October 29, 2017 wind storm, speaks to the reduction in trouble locations and damage on the system due to SRP efforts. At the present, the best measure of SRP effectiveness in a storm can be seen in a reduction of the overall storm restoration duration and the number of resources required shown in Chart 1.

3. Storm Resiliency Program Proposal

Due to the positive impact the SRP has had on major storm event resources, restoration, and cost, the Company is proposing to accelerate the program. The original SRP plan was for a 10 year time frame, which put the initial cycle of SRP wrapping up in 2021. The Company is proposing to accelerate the plan by one year, completing an additional one-third mileage during 2018, 2019, and 2020. This would increase spending by $474,333 for these three years, bringing the total SRP spend for each of these years to $1,897,333.

This would have a minimal bill impact on a per customer basis, as an average customer would see an increase of only $0.24.

By using the outage per mile per year results seen to date (Table 1 above), the impact of accelerating the SRP work can be estimated, for the actual areas and customers in the acceleration circuits. We have seen a reduction in outages per mile per year of 99%. If we accelerate 13.6 miles of work in 2018, as proposed, and see the average reduction in outage of 99%, using the past five year history we would expect to reduce the outages on these two circuits by anywhere from 1 to 2 outages, reducing customer interruptions anywhere from 1,073 to 1,273 customer interruptions, and reducing customer minutes of interruption from 53,604 to 64,604 CMI for the acceleration portion only. There are 2,015 customers served on these two circuits that would see an improvement in their reliability two years in advance.

In 2019, we would expect to see a similar reduction in outages and customer interruptions, including the additional accelerated miles in 2019 – bringing the estimated reduction in outages per mile to 3, reducing customer interruptions by an estimate of 2,546 and customer-minutes of interruption by as much as 129,208 for the accelerated circuits in 2018 and 2019 only.

In 2020, again the impact of the past two years of acceleration would be realized, plus the additional final year of acceleration, bringing the reduction in outages to an estimate of 4 to 5 outages avoided on the SRP acceleration circuits. The estimated customer impact of the acceleration project in 2020 is estimated to be 3,819 customer interruptions avoided and as much as 193,812 customer-minutes of interruption avoided.

Over all three years of the acceleration project, a total estimated reduction of 6 outages could be realized, equating to a customer impact of 7,638 customer interruptions and 687,624 customer minutes of interruption avoided years in advance, on the accelerated circuits.

4. Conclusion

Unitil embarked on a Storm Pilot Program in 2012 and 2013 in response to the increasing trend of costly and devastating storm events and the need to shorten the response time and event duration. The initial success of the targeted vegetation pilot and anticipated future savings and economic benefits to customers led to approval of the continuance of storm pilot work as an annual Storm Resiliency Program. The Company has seen a clear decline in resources needed in major storms, and a decline in the overall cost of restoration since the SRP program has been in effect. While difficult to quantify, the customer impact of shorter duration events, or the avoidance of events, has been the biggest benefit. The ability to return to normal service conditions more quickly after an event, and allow affected customers to get back to school and to work, and minimize the economic impact that storm events have on customer's lives is the real benefit. Accelerating the SRP program will bring that benefit more quickly to more customers.

Unitil Energy Systems, Inc.
Reliability Program
Vegetation Management Program
Annual Report 2018
Attachment 2

Attachment 2

UES – Capital

Reliability Study 2018

UES Capital

Reliability Study

2018

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9/5/2018

Table of Contents

1 Executive Summary

The purpose of this document is to report on the overall reliability performance of the UES Capital system from January 1, 2017 through December 31, 2017. The scope of this report will also evaluate individual circuit reliability performance over the same time period. The outage data from the following storms have been excluded from these analyses: March ’17 wind storm from 3/02/2017 00:00 to 3/03/2017 00:00 and October ’17 tropical storm from 10/29/2017 00:00 to 10/31/2017 00:00.

The following projects are proposed from the results of this study and are focused on improving the worst performing circuits as well as the overall UES Capital system reliability. These recommendations are provided for consideration and will be further developed with the intention to be incorporated into the 2019 budget development process.

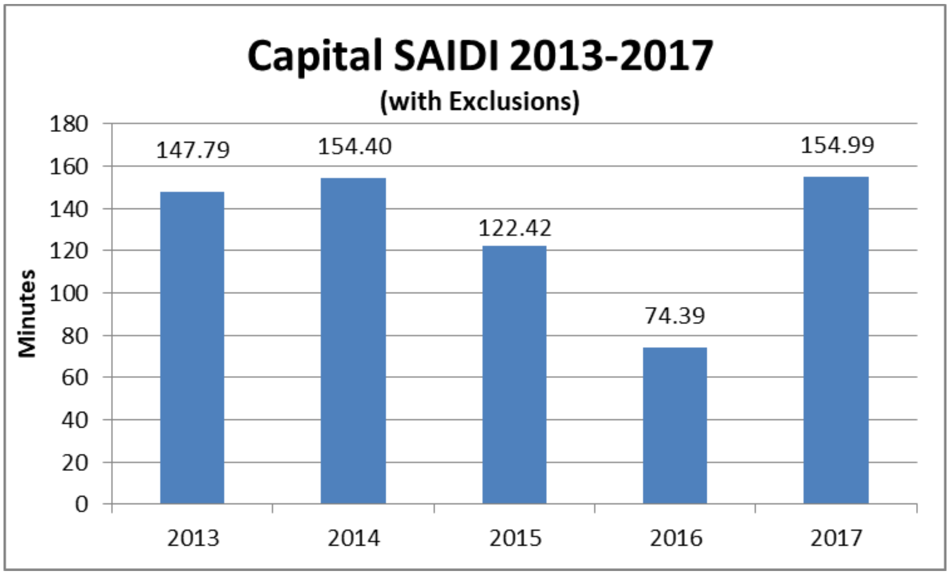
Circuit / Line / Substation	Proposed Project	Cost ($)
18W2	Install Recloser in south direction out of Bow Bog S/S	$46,612
13W1	Re-fuse Borough Rd and Old Tilton Rd, Canterbury	Minimal
8X3	Install Fusesaver on Smith-Sanborn Rd, Chichester	EWR
13W3	Replace recloser on Water St, Boscawen	$27,683
Various	Animal Guard Installation	$50,000

Note: estimates do not include overheads

UES Capital SAIDI was 154.99 minutes in 2017 after removing Major Event Days. Chart 1 below shows UES Capital SAIDI over the past five years.

Chart 1

Annual Capital SAIDI



2 Reliability Goals

The annual corporate UES Capital system reliability goals for 2017 were set at 150-132-114 SAIDI minutes. These were developed based on the historical reliability performance of the Capital system.

Individual circuits will be analyzed based upon circuit SAIDI, SAIFI, and CAIDI. Analysis of individual circuits along with analysis of the entire UES Capital system is used to identify future capital improvement projects and/or operational enhancements which may be required in order to achieve and maintain these goals.

3 Outages by Cause

This section provides a breakdown of all outages by cause code experienced during 2017. Chart 2 lists the number of interruptions due to each cause. For clarity, only those causes occurring more than 6 times are labeled. Chart 3 details the percent of total customer-minutes of interruption due to each cause. Only those causes contributing greater than 2% of the total are labeled.

Chart 2

Number of Interruptions by Cause

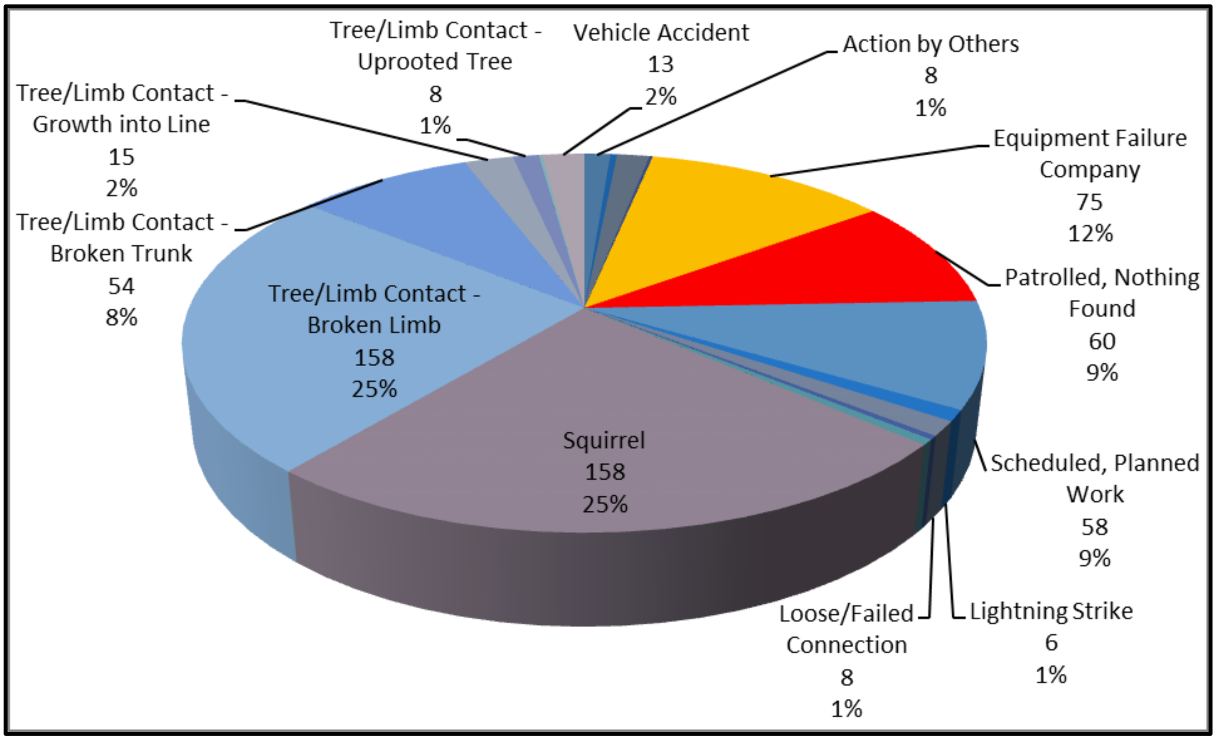
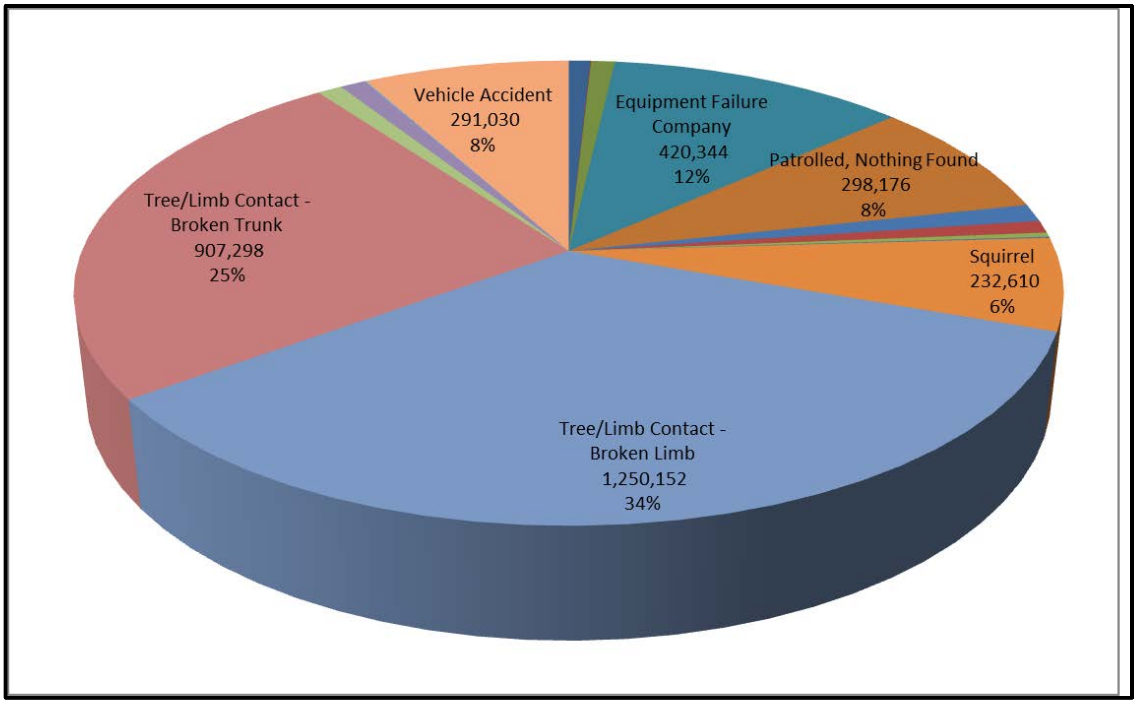


Chart 3

Customer-Minutes of Interruption by Cause



4 10 Worst Distribution Outages

The ten worst distribution outages ranked by customer-minutes of interruption during the time period from January 1, 2017 through December 31, 2017 are summarized in Table 1 below.

Table 1

Worst Ten Distribution Outages

Circuit	Description (Date/Cause)	No. of Customers Affected	No. of Customer Minutes	Capital SAIDI (min.)	Capital SAIFI
C18W2	1/18/2017 Tree/Limb Contact – Broken Trunk	1,144	224,624	7.52	.038
C13W2	8/4/2017 Tree/Limb Contact – Broken Limb	1,434	219,115	7.34	.048
C8X3	7/19/2017 Motor Vehicle Accident	2,861	173,281	5.81	.095
C18W2	10/21/2017 Patrolled, Nothing Found	930	144,119	4.83	.031
C13W2	10/25/2017 Equipment Failure Company	994	117,490	3.93	.033
C8X3	7/1/2017 Tree/Limb Contact –	447	110,133	3.69	.014

	Broken Trunk				
C16H3	2/28/2017 Equipment Failure Company	625	103,303	3.46	.021
C15W1	7/1/2017 Tree/Limb Contact – Broken Trunk	986	88,247	2.95	.033
C8X3	2/15/2017 Tree/Limb Contact – Broken Limb	202	82,568	2.76	.007
C13W2	3/14/2017 Tree/Limb Contact – Broken Limb	992	80,738	2.71	.033

Note: This table does not include outages that occurred at substations or on the subtransmission system or outages that occurred during excludable events.

5 Subtransmission and Substation Outages

This section describes the contribution of sub-transmission line and substation outages on the UES Capital system.

All substation and sub-transmission outages ranked by customer-minutes of interruption during the time period from January 1, 2017 through December 31, 2017 are summarized in Table 2 below.

Table 3 shows the circuits that have been affected by sub-transmission line and substation outages. The table illustrates the contribution of customer minutes of interruption for each circuit affected.

In aggregate, sub-transmission line and substation outages accounted for 24% of the total customer-minutes of interruption for UES Capital.

Table 2

Subtransmission and Substation Outages

Trouble Location	Description (Date/Cause)	No. of Customers Affected	No. of Customer Minutes	UES CAPITAL SAIDI (min.)	UES CAPITAL SAIFI
Line 37	10/25/2017 Equipment Failure Company	3,263	387,285	12.9	.109
Line 396	10/21/2017 Patrolled, Nothing Found	939	145,513	4.87	.031
Boscawen S/S 13T1	7/29/2017 Bird	1,488	71,424	2.39	.049
Line 37	6/2/2017 Tree/Limb Contact – Broken Trunk	3,256	99,850	3.34	.109
Line 396	5/17/2017 Tree/Limb Contact – Broken Trunk	1,157	109,410	3.66	.038
Line 34	3/27/2017 Equipment Failure Company	2,809	67,288	2.25	.094
Line 396X1	1/18/2017 Tree/Limb Contact – Broken Trunk	1,153	226,392	7.58	.038

Table 3

Contribution of Subtransmission and Substation Outages

Circuit	Trouble Location	Customer-Minutes of Interruption	% of Total Circuit Minutes	Circuit SAIDI Contribution	Number of Events
C13W1	Line 37 / Boscawen 13T1	96,315	35%	196.96	3
C13W2	Line 37 / Boscawen 13T2	195,846	34%	197.02	3
C13W3	Line 37	239,575	30%	150.01	2
C13X4	Line 37	118	100%	118.20	1
C17X1	Line 396 / Line 396X2	820	100%	410.36	3
C18W2	Line 396 / Line 396X2	477,312	74%	415.05	4
C2H1	Line 34	11,520	99%	23.90	1
C2H2	Line 34	25,464	64%	24.00	1
C2H4	Line 34	2,155	100%	51.33	1
C33X4	Line 34	1,570	9%	23.43	1
C34X4	Line 34	23	100%	23.43	1
C37X1	Line 37	26,704	67%	150.02	2
C396X2	Line 396X1	3,182	100%	454.70	3
C6X3	Line 33	26,555	44%	23.94	1

6 Worst Performing Circuits

This section compares the reliability of the worst performing circuits using various performance measures. All circuit reliability data presented in this section includes sub-transmission or substation supply outages unless noted otherwise.

6.1 Worst Performing Circuits in Past Year (1/1/17 – 12/31/17)

A summary of the worst performing circuits during the time period between January 1, 2017 and December 31, 2017 is included in the tables below.

Table 4 shows the ten worst circuits ranked by the total number of Customer-Minutes of interruption. The SAIFI and CAIDI for each circuit are also listed in this table.

Table 5 provides detail on the major causes of the outages on each of these circuits. Customer-Minutes of interruption are given for the six most prevalent causes during 2017.

Circuits having one outage contributing more than 80% of the Customer-Minutes of interruption were excluded from this analysis.

Table 4

Worst Performing Circuits Ranked by Customer-Minutes

Circuit	Customer Interruptions	Worst Event (% of CI)	Cust-Min of Interruption	Worst Event (% of CMI)	SAIDI	SAIFI	CAIDI
C8X3	8,888	32%	932,433	19%	326.03	3.108	104.91
C13W3	8,411	19%	792,905	24%	496.50	5.267	94.27
C18W2	4,751	24%	644,736	35%	560.64	4.131	135.71
C13W2	6,654	22%	574,278	38%	577.74	6.694	86.31
C13W1	2,845	17%	271,759	23%	555.75	5.818	95.52
C16H3	2,933	21%	251,893	41%	403.03	4.693	85.88
C22W3	2,960	17%	243,312	15%	152.64	1.857	82.20
C15W1	2,410	41%	154,013	57%	156.04	2.442	63.91
C4W3	1,804	16%	147,921	23%	106.65	1.301	82.00
C4W4	2,575	88%	89,281	67%	39.40	1.136	34.67

Note: all percentages and indices are calculated on a circuit basis

Table 5

Circuit Interruption Analysis by Cause

Circuit	Customer – Minutes of Interruption / # of Outages					
	Vehicle Accident	Squirrel	Scheduled, Planned Work	Tree/Limb Contact - Broken Trunk	Tree/Limb Contact - Broken Limb	Equipment Failure Company
C8X3	42,577 / 29	246,927 / 3	1,820 / 1	133,389 / 9	209,075 / 36	24,154 / 16
C13W3	35,049 / 35	1,215 / 3	340 / 4	155,495 / 10	253,814 / 30	8,386 / 7
C18W2	17,553 / 13	0 / 0	576 / 4	263,796 / 3	5,645 / 7	89,309 / 6
C13W2	9,267 / 5	0 / 0	300 / 1	0 / 0	337,575 / 14	120,835 / 4
C13W1	3,705 / 11	0 / 0	0 / 0	134,526 / 13	39,454 / 13	3,417 / 2
C16H3	0 / 0	200 / 1	8,289 / 5	77,042 / 1	23,539 / 1	103,883 / 3
C22W3	62,280 / 23	0 / 0	0 / 0	15,346 / 4	12,4379 / 14	20,899 / 7
C15W1	3,188 / 4	0 / 0	80 / 1	99,141 / 3	10,870 / 3	6,287 / 1
C4W3	11,056 / 10	1,870 / 1	2,976 / 7	5,320 / 2	61,940 / 12	2,101 / 3
C4W4	8,309 / 5	0 / 0	1,506 / 2	898 / 1	63,106 / 6	6,776 / 4

6.2 Worst Performing Circuits of the Past Five Years (2013 – 2017)

The annual performance of the ten worst circuits in terms of circuit SAIDI and SAIFI for each of the past five years is shown in the tables below. Table 6 lists the ten worst performing circuits ranked by SAIDI and Table 7 lists the ten worst performing circuits ranked by SAIFI. Table 8 lists the ten worst performing circuits ranked by SAIDI and SAIFI over the past five years.

The data used in this analysis includes all system outages except those outages that occurred during the 2016 July Wind/Thunder storm, 2014 November Cato Snowstorm, 2017 March Windstorm, and 2017 October Tropical Storm.

Table 6

Circuit SAIDI

Circuit Ranking (1 = worst)	2017		2016		2015		2014		2013	
	Circuit	SAIDI	Circuit	SAIDI	Circuit	SAIDI	Circuit	SAIDI	Circuit	SAIDI
1	C13W2	577.74	C21W1A	892.82	C21W1A	803.71	C15W2	794.83	C16H1	1,524.26
2	C18W2	560.64	C7W3	272.49	C34X2	399.45	C22W3	729.57	C375X1	1,018.00
3	C13W1	555.75	C34X2	244.8	C13W3	357.44	C35X1	573.63	C37X1	861.07
4	C13W3	496.50	C37X1	176.22	C375X1	318.05	C24H1	570.48	C13W2	744.95
5	C396X2	454.70	C18W2	155.42	C14H2	288.10	C24H2	545.14	C13W1	739.74
6	C17X1	410.37	C15W1	147.96	C16X4	281.37	C22W1	534.36	C16X5	720.50
7	C16H3	403.03	C4X1	146.38	C16H1	281.30	C22W2	512.65	C8X3	708.72
8	C8X3	326.03	C13W1	140.76	C7W3	281.18	C15W1	499.87	C13W3	609.67
9	C33X4	246.98	C22W3	136.51	C16H3	280.82	C7W3	444.56	C24H1	524.03
10	C8H2	246.67	C13W3	117.09	C16X5	280.05	C38W	441.97	C18W2	521.30

Table 7

Circuit SAIFI

Circuit Ranking (1 = worst)	2017		2016		2015		2014		2013	
	Circuit	SAIDI	Circuit	SAIDI	Circuit	SAIDI	Circuit	SAIDI	Circuit	SAIDI
1	C13W2	6.694	C21W1 A	3.993	C21W1 A	6.356	C24H1	7.143	C13W2	7.068
2	C13W1	5.818	C37X1	2.418	C16X4	5.023	C24H2	6.987	C16X5	5.500
3	C13W3	5.267	C18W2	1.995	C16H1	5.020	C15W2	6.597	C37X1	5.412
4	C16H3	4.693	C15W1	1.938	C16X5	5.000	C22W3	5.832	C13W1	5.405
5	C18W2	4.131	C13W1	1.785	C16X6	5.000	C3H1	4.251	C22W3	4.849
6	C8H2	3.122	C1X7P	1.778	C375X1	5.000	C22W1	4.034	C4W3	4.574
7	C8X3	3.108	C4X1	1.738	C16H3	4.998	C38W	4.022	C13W3	4.547
8	C17X1	3.000	C22W3	1.509	C7W3	4.850	C22W2	4.000	C7W3	4.547
9	C396X 2	3.000	C7W3	1.396	C13W3	4.567	C7W3	3.982	C18W2	4.337
10	C37X1	2.770	C13W3	1.348	C18W2	4.127	C14X3	3.500	C16H1	4.120

Table 8

Worst Performing Circuit past Five Years

SAIDI				SAIFI		
Circuit Ranking	**Circuit**	**# Appearances**		**Circuit Ranking**	**Circuit**	**# Appearances**
1	C21W1A	2		**1**	C7W3	4
2	C13W1	3		**2**	C13W3	4
3	C13W3	4		**3**	C13W1	3
4	C18W2	3		**4**	C13W2	2
5	C7W3	3		**5**	C18W2	4
6	C15W2	1		**6**	C37X1	3
7	C13W2	2		**7**	C22W3	3
8	C37X1	2		**8**	C15W1	1
9	C24H1	2		**9**	C21W1A	2
10	C22W3	2		**10**	C15W2	1

6.3 System Reliability Improvements (2017 and 2018)

Vegetation management projects completed in 2017 or planned for 2018 that are expected to improve the reliability of the 2017 worst performing circuits are included in table 9 below. Table 10 below details electric system upgrades that are scheduled to be completed in 2018 or were completed in 2017 that were performed to improve system reliability.

Table 9

Vegetation Management Projects on Worst Performing Circuits

Circuit(s)	Year of Completion	Project Description
13W2	2017	Planned Hazard Tree Mitigation / Mid-Cycle Pruning
13W3	2017	SRP
22W3	2017	SRP
18W2	2017	Planned Hazard Tree Mitigation
396X2	2017	Cycle Pruning
13W1	2017	Planned Hazard Tree Mitigation / Mid-Cycle Pruning
15W1	2017	SRP
8X3	2017	Cycle Pruning / Planned hazard Tree Mitigation
4W3	2017	Cycle Pruning

Table 10

Electric System Improvements Performed to Improve Reliability

Circuit(s)	Year of Completion	Project Description
22W3	2017	Sectionalizer Installation
15W1	2017	Fusesaver Installation
15W1	2017	Hydraulic Recloser Installation
8X3	2017	Fusesaver Installation
374 and 375 Line	2017	Autoscetionalizing Scheme
Bow Junction	2017	Autoscetionalizing Scheme

7 Tree Related Outages in Past Year (1/1/17 – 12/31/17)

This section summarizes the worst performing circuits by tree related outage during the time period between January 1, 2017 and December 31, 2017.

Table 11 shows the ten worst circuits ranked by the total number of Customer-Minutes of interruption. The number of customer-interruptions and number of outages are also listed in this table.

All streets on the UES CAPITAL system with three or more tree related outages are shown in Table 12 below. The table is sorted by number of customers interrupted and customer-minutes of interruption.

Table 11

Worst Performing Circuits – Tree Related Outages

Circuit	Customer-Minutes of Interruption	Number of Customers Interrupted	No. of Interruptions
C13W3	412,112	5,933	44
C8X3	388,747	2,898	53
C13W2	345,505	3,989	16
C18W2	269,441	2,616	10
C13W1	177,220	1,754	29
C22W3	140,925	1,886	19
C15W1	110,010	1,234	6
C16H3	108,357	942	3
C4W3	67,379	935	15
C4W4	64,003	2,307	7

Table 12

Multiple Tree Related Outages by Street

Circuit	Street	Town	# Outages	Customer-Minutes of Interruption	No. of Customer Interruptions
C13W3	High St	Boscawen	6	109,141	1,259
C13W2	Queen St	Boscawen	5	3,242	133
C13W1	Old Tilton Rd	Canterbury	5	29,348	178
C22W3	Albin Rd	Bow	4	77,788	1,317
C8X3	Josiah Bartlett Rd	Concord	4	14,096	161
C13W3	Daniel Webster Hwy	Boscawen	3	8,228	128
C13W2	Pickard Rd	Canterbury	3	8,891	68
C8X3	Lane Rd	Chichester	3	16,741	166
C4W4	District #5 Rd	Concord	3	1,176	18
C15W1	Oak Hill Rd	Concord	3	18,745	217
C4W3	Mountain Rd	Concord	3	23,367	154
C13W3	Old Turnpike Rd	Salisbury	3	24,278	260
C13W3	West Salisbury Rd	Salisbury	3	23,809	186

8 Failed Equipment

This section is intended to clearly show all equipment failures throughout the study period from January 1, 2017 through December 31, 2017. Chart 3 shows all equipment failures throughout the study period. Chart 4 shows each equipment failure as a percentage of the total failures within this same study period. The number of equipment failures in each of the top four categories of failed equipment for the past five years are shown below in Chart 5.

Chart 3

Equipment Failure Analysis by Cause

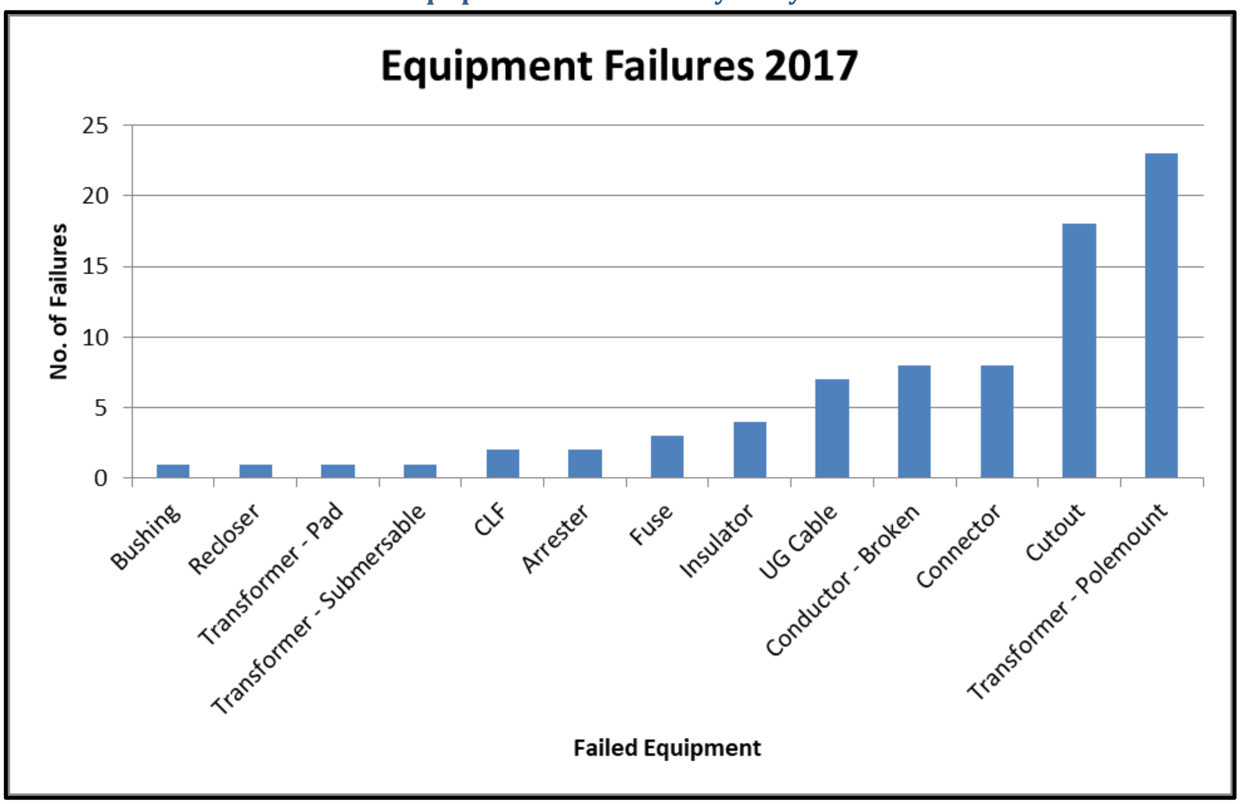


Chart 4

Equipment Failure Analysis by Percentage of Total Failures

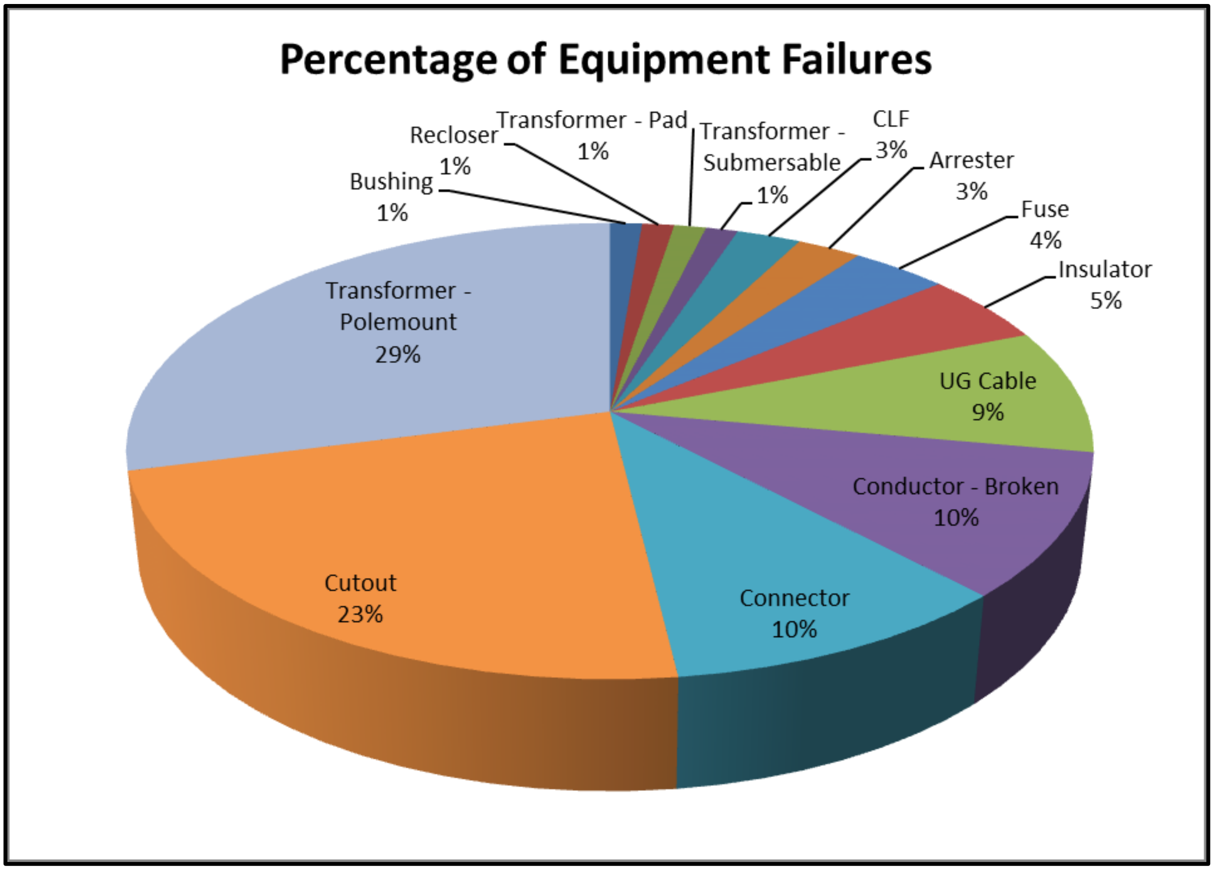
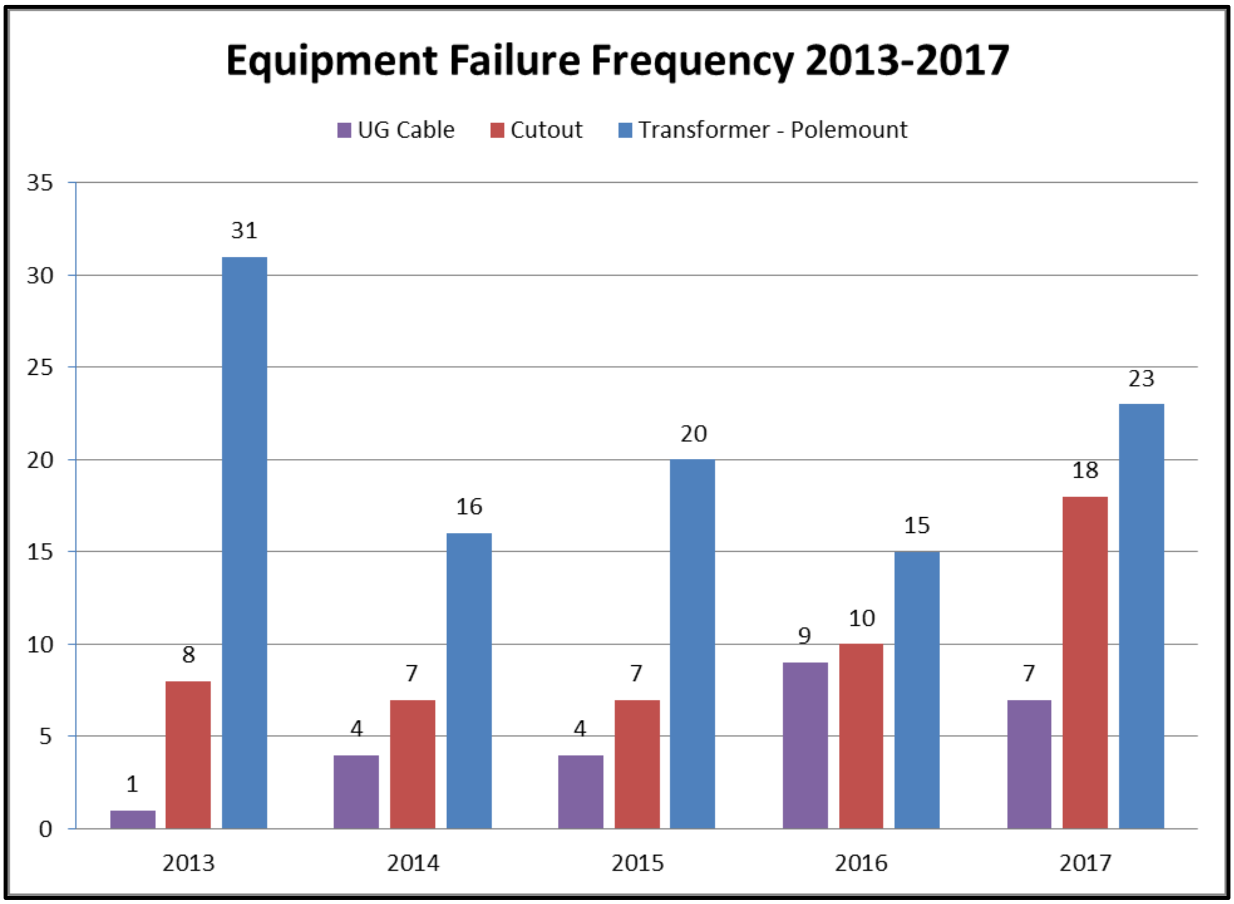


Chart 5
Annual Equipment Failures by Category (top three)

Barring the 2013 year, the top four equipment failures are trending upward. Of particular note, the cutout failures have seen the most growth over the four year time frame. There is not currently a cutout replacement program, however, a program will be researched and potentially proposed in future study.



9 Multiple Device Operations in Past Year (1/1/17 – 12/31/17)

A summary of the devices that have operated four or more times from January 1, 2017 to December 31, 2017 are included in table 13 below.

Table 13

Multiple Device Operations

Circuit	Device	Number of Operations	Customer Minutes	Customer Interruptions
C8X3	Fuse, Pole 1, Smith Sanborn Rd, Chichester	8	38,116	539
13W2	Fuse, Pole 22, North Main St, Boscawen	6	42,046	702
C13W1	Fuse, Pole 38, West Rd, Canterbury	5	807	10
C4W3	Fuse, Pole 114, Snow Pond Rd, Concord	5	9,962	135
C4W3	Recloser, Pole 53, Sewalls Falls Rd, Concord	5	69,911	861
C13W3	Recloser, Pole 84, High St, Boscawen	4	125,555	1,260
C13W3	Fuse, Pole 1, Forest Ln, Boscawen	4	10,922	127
C13W1	Recloser, Pole 2, Old Tilton Rd, Canterbury	4	22,339	210
C4W3	Fuse, Pole 158, Mountain Rd, Concord	4	865	12
C4W4	Fuse, Pole 22, District #5 Rd, Concord	4	708	12
C13W2	Fuse, Pole 62, Chelsey St, Concord	4	20,515	211

10 Other Concerns

This section is intended to identify other reliability concerns that would not necessarily be identified from the analysis above.

10.1 Narrow sub-transmission ROW expansion

The UES-Concord sub-transmission system has some areas where the Right Of Way (ROW) is narrow, thus, even after pruning trees to the edge of the ROW we leave our system vulnerable to damage by falling trees. Historically, Unitil has experienced noticeably more outages, due to falling trees, on lines that are in narrow ROW in comparison to lines in larger ROW. Unitil has been able to successfully expand ROW tree lines in 2017 and will continue these efforts in 2018. This effort is expected to allow effective tree mitigation in the problem areas.

10.2. 13.8kV Underground Electric System Degradation

The 13.8kV underground electric system has been experiencing connector and conductor failures at an average rate of 0.8 per year for the last 5 years. There were 3 cable failures in the past two years. This does not include scheduled replacement of hot terminations identified by inspection; hot terminations have been identified and replaced regularly, without causing outage. In 2015, a study on this system was completed. It identified age and use of 200A connectors may be a contributing factor to failures. Energized transfer capability is being built into this underground system to reduce the number of outages experienced by customers, during equipment replacement.

10.3. Alternate Mainline for Large 34.5kV Circuits

Circuit 8X3 has the largest customer exposure on the capital system at 2,764 customers with an 11.6MVA peak, in 2016. This circuit has no alternate feeds to restore customers during mainline outages.

Building an alternate mainline to reduce customer exposure and allow an alternate feed during contingency scenarios is the ultimate goal for this area. Three alternatives where reviewed. One involved constructing a pole line outside of UES territory, one involved double circuiting, and the final involved rebuilding Horse Corner Rd. The Horse Corner Rd route is preferred because it will create an alternate pole line and does not involve joint construction with Eversource. Extending mainline through Short Falls Rd into Epsom will potentially allow for a new circuit to be created, allowing for good tie capability and a large increase in reliability.

10.4. URD’s Utilizing Direct Buried Cable of 1970’s vintage

Direct buried cable URD’s are failing at an increasing rate, about 1-3 failures per year as of 2015. When a direct buried cable fails, Unitil splices a small section of new cable into the run of aged cable. The remaining aged cable in that area is just as susceptible to failure, so additional failures persist more frequently. When cable in conduit fails, entire runs of cable are replaced, preventing this issue. This can’t be done easily for direct buried due to cost and digging permissions. Some options to help mitigate this problem: one is to improve dielectric strength of existing cable with cable injection; two is to reduce the operating voltage of a URD and three replace runs of direct buried cable with conduit and new conductor. Option one and two are not ideal because aged direct buried cable typically has other concerns such as a degrading neutral. Option three is preferred and is being done now but it is expensive and requires implementing multiyear plans to reduce the impact of this cost.

10.5. Single Phase Underground Loop-Feed at Court St

Identified Concern

The single-phase underground cable at Court St that is used as a redundant feed for several customers on North State St is left un-energized because it doesn’t normally feed customers. There is a concern that if there is a fault on this section of cable, it could take out Circuit 21W1A. With the cable left un-energized, we wouldn’t know if there was a problem with the cable until it was energized.

Recommendation

Install an interrupter in the single phase loop out of MH22.

11 Recommendations

This following section describes recommendations on circuits, sub-transmission lines and substations to improve overall system reliability. The recommendations listed below will be compared to the other proposed reliability projects on a system-wide basis. A cost benefit analysis will determine the priority ranking of projects for the 2019 capital budget. All project costs are shown without general construction overheads.

11.1. Circuit 18W2: Install Reclosers in South Direction out of Bow Bog Substation

11.1.1. Identified Concerns

Circuit 18W2 has been in the list of 10 worst circuits in regards to SAIDI and SAIFI for three of the last five years. In the past five years since 2013, the 18W2 recloser has operated four times due to faults on the mainline.

11.1.2. Recommendations

Install a Recloser in Southern Direction out of Bow Bog Substation and a Sectionalizer on Allen Rd.

Estimated Project Cost (without construction overheads): $46,612

Estimated Annual Savings – Customer Minutes: 4,616, Customer Interruptions: 71

11.2. Circuit 13W1: Refuse Borough Rd and Old Tilton Rd, Canterbury

11.2.1. Identified Concerns

Borough Rd and Old Tilton Rd in Canterbury appeared on the list of most interrupted customers with an average of 11 non-major outages and 10 non-major outages respectively.

11.2.2. Recommendations

Install cutouts and a 40N fuse at Pole 72, Borough Rd.

Replace solid blade with 65N fuse at Pole 23 Old Tilton Rd.

Install cutouts and an 85N fuse at Pole 9 Old Tilton Rd.

Estimated Project Cost (without construction overheads): minimal

Estimated Annual Savings – Customer Minutes: 3003, Customer Interruptions: 33

11.3. Circuit 8X3: Install a Fusesaver on Smith-Sanborn Rd

11.3.1. Identified Concern

The fuse a P.1 Smith-Sanborn Rd. in Chichester had eight operations in 2017, two of which were squirrels, four were patrolled with nothing found and two were tree/limb contact. Customers on average saw 9-11 outages during 2017, according to a yearly outage report.

11.3.2. Recommendation

Install a wire-mount fuse saving device at Pole 1 on Smith-Sanborn Rd in Chichester to reduce the number of momentary outages.

Estimated Project Cost (without applied overheads): $2,525

Estimated Annual Savings – Customer Minutes of Interruption: 6488, Customer Interruptions: 77

11.4. Circuit 13W3: Replace Recloser on Water St, Boscawen

11.4.1. Identified Concern

The recloser on Pole 27-1 High St, Boscawen does not coordinate with the down-line fusing. Providing better coordination will allow downline faults to have minimal impact, and prevent outages from rolling up to this device.

11.4.2. Recommendation

Replace the V4H 100A recloser on Pole 27-1 High St, Boscawen with a V4L 140A recloser.

Estimated Project Cost (without applied overheads): $27,683

Estimated Annual Savings – Customer Minutes of Interruption: 1,732, Customer Interruptions: 27

11.5. Miscellaneous Circuit Improvements to Reduce Recurring Outages

11.5.1. Identified Concerns & Recommendations

The following concerns were identified based on a review of Tables 10 & 11 of this report; Multiple Tree Related Outages by Street and Multiple Device Operations respectively.

Mid-Cycle Forestry Reviews

The areas identified below experienced three or more tree related outages in 2017. It is recommended that a forestry review of these areas be performed in 2018 in order to identify and address any mid-cycle growth or hazard tree problems.

- C13W1, Old Tilton Rd, Canterbury

- C22W3, Albin Rd, Bow
- C8X3, Josiah Bartlett Rd, Concord
- C13W3, Daniel Webster Hwy, Boscawen
- C13W2, Pickard Rd, Canterbury
- C8X3, Lane Rd, Chichester
- C4W4, District #5 Rd, Concord
- C15W1, Oak Hill Rd, Concord
- C4W3, Mountain Rd, Concord
- C13W3, Old Turnpike Rd, Salisbury
- C13W3, West Salisbury Rd, Salisbury

Animal Guard Installation Recommendations

The area identified below experienced three or more patrolled nothing found / animal outages in 2017.

Squirrel and patrolled, nothing found outages accounted for 25% and 9%, respectively, of the total number of interruptions for the Capital system in 2017. The proposed project is to install the typical animal guard devices at the following locations due to the higher concentration of outages.

Some of these streets have already had work done on them. The rest are identified by a number of transformers to have animal guards installed after the location name.

- C4W3, Snow Pond Rd, Concord
- C4W3, Mountain Rd, Concord (34)
- C4W3, Hoit Rd, Concord (36)
- C6X3, Currier Rd, Concord (13)
- C22W3, Timmins Rd, Bow (11)
- C18W2, Allen Rd, Bow

- C7W3, Knox Rd, Bow (16)
- C8X3, Smith Sanborn Rd, Chichester
- C8X3, Ferrin Rd, Chichester
- C8X3, Mason Rd, Chichester (11)
- C8X3, Horse Corner Rd, Chichester (10)
- C13W1, West Rd, Canterbury (50)
- C13W3, Corn Hill Rd, Boscawen
- C13W2, Queen St, Boscawen
- C13W3, Center Rd, Salisbury (11)
- C13W3, Little Hill Rd, Webster (21)

Estimate: $50,000 to install animal protective devices to all of these transformers

Estimated Annual Savings – Customer Minutes of Interruption: 32,241

Customer Interruptions: 412

12 Conclusion

During 2017, tree related outages still present one of the largest problems in the UES-Capital System, compared to other causes. Although compared to previous years, the worst performing circuits have seen a dramatic decrease in Customer Minutes of Interruption from tree related outages. Enhanced tree trimming efforts are still being implemented, which is expected to improve reliability for most of the worst performing circuits identified in this study.

Squirrel related outages mark the largest cause of outages in 2017. Animal guards are being placed on equipment whenever an animal causes an outage. In addition, when there is an animal-related outage, any equipment in the vicinity will be checked. If nearby equipment does not have animal guards, the animal guards will be installed at that location.

Also, all streets and circuits identified as having high numbers of animal related outages will be checked and proper animal protection will be installed where applicable.

Motor Vehicle Accidents (MVA) have caused about 3 times as many customer minutes of interruption, in 2015, as the two previous years. MVA's still are amongst the top three contributors to SAIFI and SAIDI. One 2.5 mile stretch of Route 3A in Bow has been identified as a recurring problem area over the last three years. Solutions will require state and local review and support. A summary of work and potential project proposal will be included in a future year's study.

Recommendations developed from this study are mainly focused on reducing the impact of multiple permanent outages and improving reliability of the sub transmission system. This report is also intended to assist Unitil Forestry in identifying areas of the system that are being frequently affected by tree related outages to allow proactive measures to be taken. In addition, new ideas and solutions to reliability problems are always being explored in an attempt to provide the most reliable service possible.

Attachment 3

UES - Seacoast

Reliability Study 2018

Unitil Energy Systems - Seacoast

Reliability Study

2018

Prepared By:

C. Riffle

Unitil Service Corp.

September 11, 2018

Table of Contents

1 Executive Summary

The purpose of this document is to report on the overall reliability performance of the UES-Seacoast system from January 1, 2017 through December 31, 2017. The scope of this report will also evaluate individual circuit reliability performance over the same time period. The following projects are proposed from the results of this study and are focused on improving the worst performing circuits as well as the overall UES-Seacoast system reliability. These recommendations are provided for consideration and will be further developed with the intention to be incorporated into the 2019 budget development process.

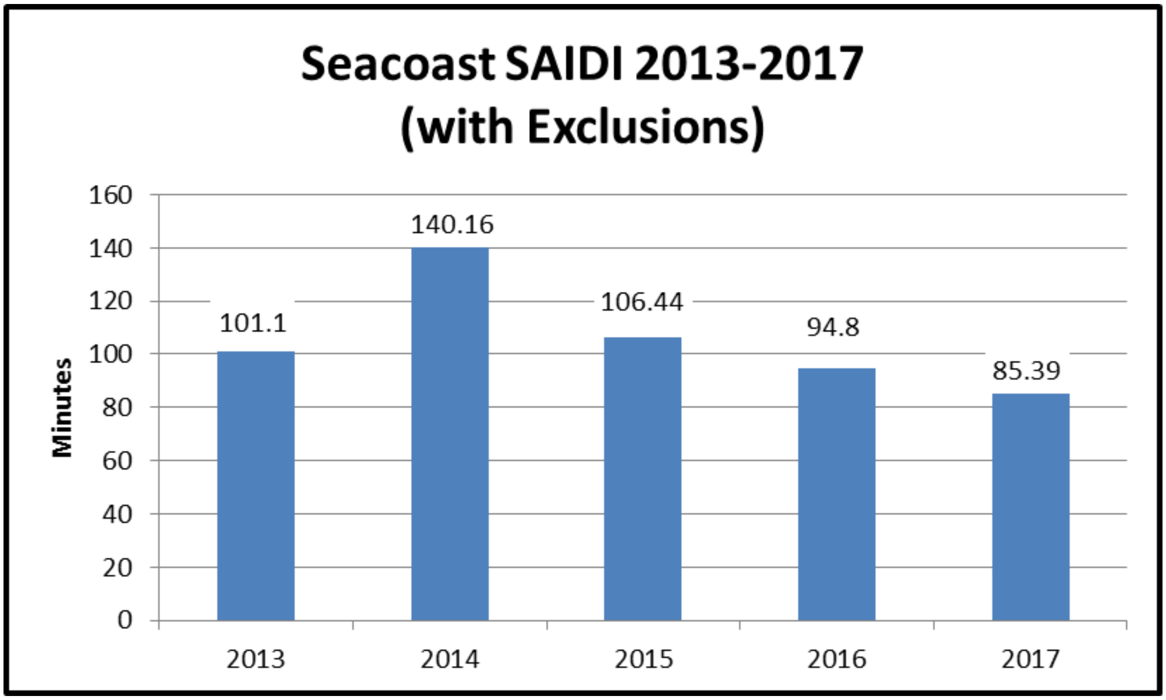
Circuit / Line / Substation	Proposed Project	Cost ($)
43X1	Re-conductor Willow Road with Spacer Cable	$450,000
6W1	Re-conductor Depot Road with Spacer Cable	$175,000
13W1	Install Fusesaver on Culver St	$9,000
19X2	Distribution Automation Scheme with Portsmouth Ave	$200,000
3345 / 3356	Install Motor Operated Switches Timberlane Substation	$30,000
17W1	Install Reclosers Sectionalizer and fusing on North Shore Road	$30,000

Note: estimates do not include overheads

UES Seacoast SAIDI was 85.39 minutes in 2017 after removing IEEE Major Event Days. Chart 1 below shows UES Seacoast SAIDI over the past five years.

Chart 1

Annual UES-Seacoast SAIDI



2 Reliability Goals

The annual corporate UES-Seacoast system reliability goals for 2017 were set at 128-111-93 SAIDI minutes. These were developed based on the historical reliability performance of the Seacoast system.

Individual circuits will be analyzed based upon circuit SAIDI, SAIFI, and CAIDI. Analysis of individual circuits along with analysis of the entire UES-Seacoast system is used to identify future capital improvement projects and/or operational enhancements which may be required in order to achieve and maintain these goals.

3 Outages by Cause

This section provides a breakdown of all outages by cause code experienced during 2017. Chart 2 lists the number of interruptions due to each cause. For clarity, only those causes occurring more than 6 times are labeled. Chart 3 details the percent of total customer-minutes of interruption due to each cause. Only those causes contributing greater than 2% of the total are labeled.

Chart 2

Number of Interruptions by Cause

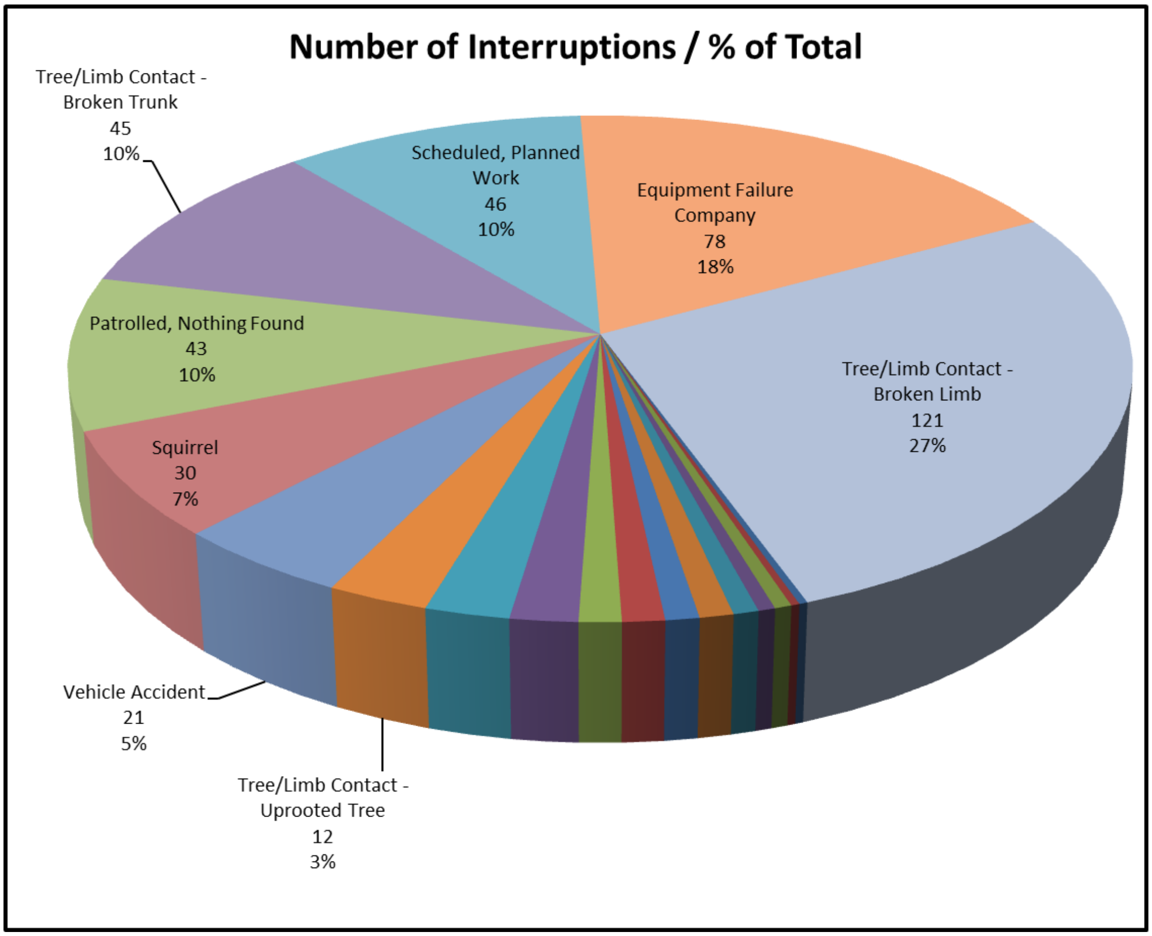
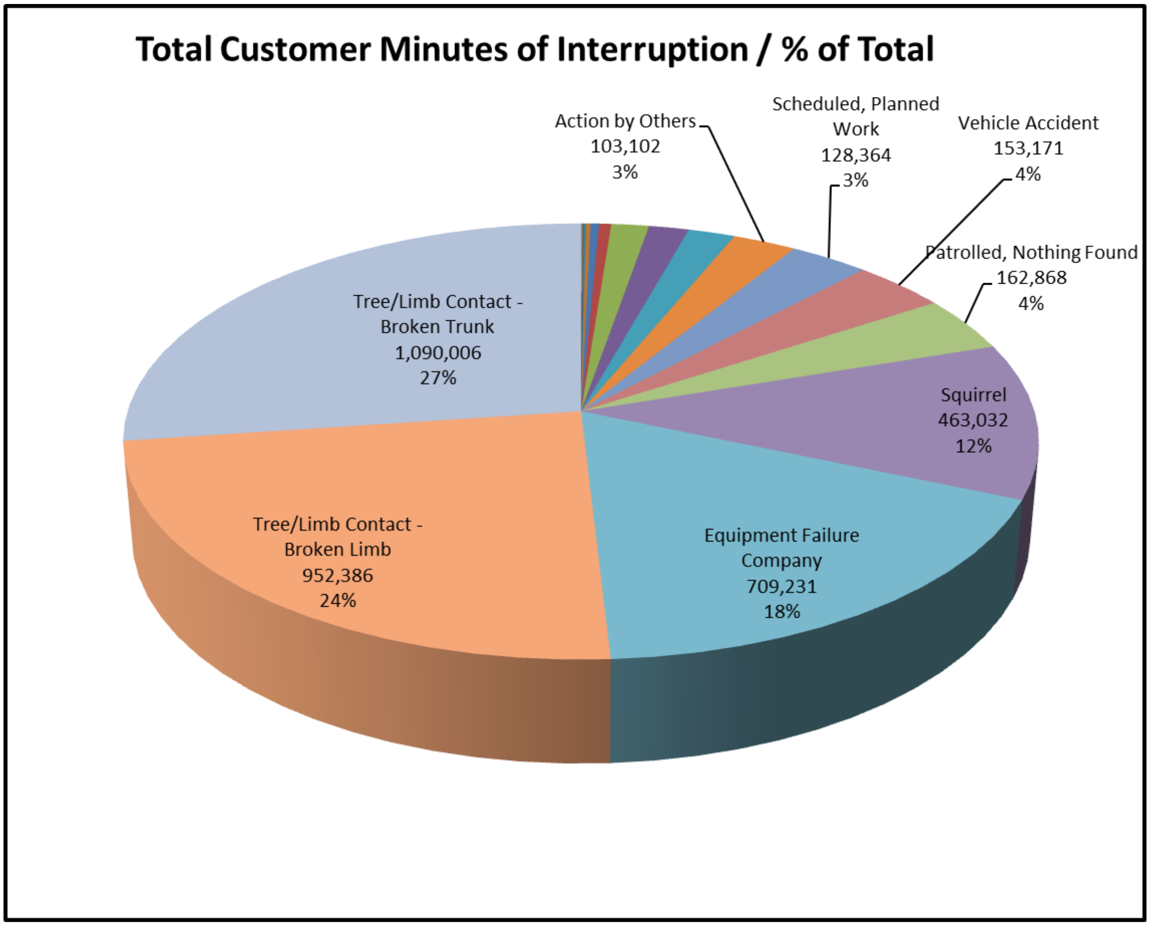


Chart 3

Customer-Minutes of Interruption by Cause



4 10 Worst Distribution Outages

The ten worst distribution outages ranked by customer-minutes of interruption during the time period from January 1, 2017 through December 31, 2017 are summarized in Table 1 below.

Table 1

Worst Ten Distribution Outages

Circuit	Description (Date/Cause)	No. of Customers Affected	No. of Customer Minutes	UES Seacoast SAIDI (min.)	UES Seacoast SAIFI
E51X1	03/09/2017 Tree/Limb Contact - Broken Trunk	822	210,966	4.49	0.017
E22X1	03/02/2017 Tree/Limb Contact - Broken Trunk	1,909	155,584	3.31	0.041
E22X1	03/09/2017 Tree/Limb Contact - Broken Trunk	1,161	148,868	3.17	0.025
E54X2	12/23/2017 Tree/Limb Contact - Broken Limb	1,020	128,282	2.73	0.022
E18X1	09/07/2017 Equipment Failure Company	1,796	127,537	2.71	0.038
E43X1	06/07/2017 Equipment Failure Company	685	106,751	2.27	0.015
E21W1	01/31/2017 Action by Others	1,370	97,681	2.08	0.029
E15X1	08/23/2017 Tree/Limb Contact - Broken Trunk	990	82,446	1.75	0.021
E43X1	03/02/2017 Tree/Limb Contact - Broken Limb	1,862	70,756	1.51	0.04
E58X1	09/07/2017 Tree/Limb Contact - Broken Trunk	587	67,505	1.44	0.012

Note: This table does not include outages that occurred at substations or on the subtransmission system or outages that occurred during excludable events.

5 Subtransmission and Substation Outages

This section describes the contribution of sub-transmission line and substation outages on the UES-Seacoast system.

All substation and sub-transmission outages ranked by customer-minutes of interruption during the time period from January 1, 2017 through December 31, 2017 are summarized in Table 2 below.

Table 3 shows the circuits that have been affected by sub-transmission line and substation outages. The table illustrates the contribution of customer minutes of interruption for each circuit affected.

In aggregate, sub-transmission line and substation outages accounted for 19% of the total customer-minutes of interruption for UES-Seacoast.

Table 2

Subtransmission and Substation Outages

Trouble Location	Description (Date/Cause)	No. of Customers Affected	No. of Customer Minutes	Seacoast SAIDI (min.)	Seacoast SAIFI
Gilman Lane Substation	01/04/2017 Squirrel	5,033	307,103	6.54	0.107
3359 Line	03/23/2017 Tree/Limb Contact - Broken Trunk	2,972	150,269	3.20	0.063
3342 Line	04/21/2017 Scheduled, Planned Work	3,101	86,828	1.85	0.066
3348 Line	09/02/2017 Equipment Failure Company	3,006	221,308	4.71	0.064

Table 3
Contribution of Subtransmission and Substation Outages

Circuit	Trouble Location	Customer-Minutes of Interruption	% of Total Circuit Minutes	Circuit SAIDI Contribution	Number of Events
E7X2	3348 Line	128,664	92%	72	1
E7W1	3348 Line	92,644	95%	76.06	1
E3H3	3342 Line	14,084	67%	27.94	1
E3W4	3342 Line	46,032	80%	27.95	1
E3H1	3342 Line	19,124	100%	28.00	1
E3H2	3342 Line	7,588	90%	28.10	1
E59X1	3359 Line	61,740	48%	60.00	1
E15X1	3359 Line	48,461	25%	49.05	1
E23X1	3359 Line	40,068	44%	42.04	1
E19X2	Gilman Lane Substation	34,938	67%	53.83	1
E1H4	Gilman Lane Substation	26,190	100%	53.56	1
E19H1	Gilman Lane Substation	8,802	21%	54.00	1
E19X3	Gilman Lane Substation	208,715	89%	63.59	1
E1H3	Gilman Lane Substation	28,458	88%	54.52	1

6 Worst Performing Circuits

This section compares the reliability of the worst performing circuits using various performance measures. All circuit reliability data presented in this section includes sub-transmission or substation supply outages unless noted otherwise.

6.1 Worst Performing Circuits in Past Year (1/1/17 – 12/31/17)

A summary of the worst performing circuits during the time period between January 1, 2017 and December 31, 2017 is included in the tables below.

Table 4 shows the ten worst circuits ranked by the total number of Customer-Minutes of interruption. The SAIFI and CAIDI for each circuit are also listed in this table.

Table 5 provides detail on the major causes of the outages on each of these circuits. Customer-Minutes of interruption are given for the six most prevalent causes during 2017.

Circuits having one outage contributing more than 80% of the Customer-Minutes of interruption were excluded from this analysis.

Table 4

Worst Performing Circuits Ranked by Customer-Minutes

Circuit	Customer Interruptions	Worst Event (% of CI)	Cust-Min of Interruption	Worst Event (% of CMI)	SAIDI	SAIFI	CAIDI
E22X1	4,883	39%	446,194	35%	238.1	2.606	91.38
E51X1	1,727	52%	303,368	26%	158.75	0.904	175.66
E58X1	2,477	24%	298,810	23%	134.36	1.114	120.63
E6W1	3,609	10%	237,618	19%	269.71	4.096	65.84
E43X1	2,759	25%	199,702	53%	107.19	1.481	72.38
E18X1	2,532	71%	197,656	65%	110.36	1.414	78.06
E15X1	2,506	36%	190,207	42%	192.52	2.536	75.9
E17W1	1,294	22%	131,275	30%	72.09	0.711	101.45
E59X1	1,539	67%	128,631	48%	125.01	1.496	83.58
E47X1	1,279	38%	125,666	37%	80.04	0.815	98.25

Note: all percentages and indices are calculated on a circuit basis

Table 5

Circuit Interruption Analysis by Cause

Circuit	Customer - Minutes of Interruption / # of Outages					
	Tree/Limb Contact - Broken Limb	Squirrel	Tree/Limb Contact - Broken Trunk	Equipment Failure Company	Vehicle Accident	Patrolled, Nothing Found
E22X1	71,461 / 2	0 / 0	309,866 / 5	7,829 / 3	0 / 0	0 / 0
E51X1	67,288 / 4	4,183 / 1	214,294 / 2	664 / 2	5,716 / 1	9,452 / 3
E58X1	58,563 / 7	0 / 0	114,361 / 4	31,694 / 7	84,160 / 3	5,755 / 1
E6W1	134,505 / 11	0 / 0	79,129 / 3	211 / 1	0 / 0	3,993 / 3
E43X1	91,094 / 6	0 / 0	484 / 1	107,145 / 3	93 / 1	331 / 1
E18X1	35,897 / 7	0 / 0	13,020 / 2	147,004 / 5	0 / 0	375 / 1
E15X1	12,129 / 2	6,600 / 2	99,721 / 3	15,647 / 3	0 / 0	7,474 / 2
E17W1	0 / 0	0 / 0	660 / 1	68,817 / 5	6,198 / 2	54,170 / 3
E59X1	12,622 / 4	38,325 / 1	3,314 / 1	3,626 / 3	0 / 0	9,004 / 1
E47X1	36,119 / 5	47,508 / 2	21,042 / 1	0 / 0	13,222 / 2	1,433 / 2

6.2 Worst Performing Circuits of the Past Five Years (2013 – 2017)

The annual performance of the ten worst circuits in terms of circuit SAIDI and SAIFI for each of the past five years is shown in the tables below. Table 6 lists the ten worst performing circuits ranked by SAIDI and Table 7 lists the ten worst performing circuits ranked by SAIFI. Table 8 lists the ten worst overall performing circuits ranked by average SAIDI and SAIFI over the past five years.

The data used in this analysis includes all system outages except those outages that occurred during major event days in 2016 and 2017, 2014 Snowstorm Cato and the 3342/3353 Line Outage in 2014.

Table 6

Circuit SAIDI

Circuit Ranking (1 = worst)	2017		2016		2015		2014		2013	
	Circuit	SAIDI	Circuit	SAIDI	Circuit	SAIDI	Circuit	SAIDI	Circuit	SAIDI
1	E54X2	275.94	E3H2	463.53	E6W1	429.20	E6W1	392.13	E6W1	385.59
2	E6W1	269.71	E7W1	375.29	E58X1	371.96	E19X3	358.77	E27X1	273.70
3	E19H1	254.56	E3H3	255.03	E47X1	362.03	E54X1	304.14	E47X1	265.13
4	E22X1	238.10	E54X2	249.35	E6W2	306.70	E20H1	271.23	E18X1	255.74
5	E5H1	200.60	E6W1	241.11	E51X1	201.87	E18X1	258.98	E21W1	249.97
6	E15X1	192.52	E43X1	226.55	E22X1	168.43	E43X1	183.86	E13W2	247.93
7	E51X1	158.75	E21W2	214.57	E56X2	138.86	E51X1	180.90	E59X1	196.87
8	E58X1	134.36	E17W2	210.69	E17W2	136.96	E21W1	170.41	E15X1	140.18
9	E59X1	125.01	E58X1	203.82	E27X1	126.50	E1H3	158.85	E22X1	136.31
10	E22X2	117.33	E54X1	196.61	E3W4	97.95	E1H4	158.03	E43X1	125.04

Table 7

Circuit SAIFI

Circuit Ranking (1 = worst)	2017		2016		2015		2014		2013	
	Circuit	SAIFI	Circuit	SAIFI	Circuit	SAIFI	Circuit	SAIFI	Circuit	SAIFI
1	E6W1	4.096	E43X1	2.945	E47X1	3.824	E20H1	4.287	E21W1	3.269
2	E22X1	2.606	E3H2	2.867	E6W1	2.871	E51X1	3.558	E6W1	2.955
3	E15X1	2.536	E21W2	2.641	E51X1	2.511	E6W2	3.288	E27X1	2.893
4	E54X2	2.271	E17W2	2.309	E58X1	2.354	E19X3	3.090	E18X1	2.656
5	E19H1	2.012	E21W1	2.198	E2X3	2.176	E6W1	2.730	E13W2	2.580
6	E23X1	1.527	E58X1	2.107	E22X1	1.922	E11X1	2.451	E43X1	2.573
7	E59X1	1.496	E22X1	1.922	E17W2	1.860	E21W1	2.315	E47X1	2.553
8	E43X1	1.481	E27X1	1.917	E13X3	1.466	E43X1	2.133	E7X2	2.092
9	E18X1	1.414	E54X1	1.892	E13W1	1.444	E22X1	2.120	E56X1	1.925
10	E19X2	1.387	E6W1	1.772	E21W2	1.425	E18X1	1.840	E15X1	1.914

Table 8

Worst Performing Circuit past Five Years

SAIDI			SAIFI		
Circuit Ranking (1 = worst)	**Circuit**	**# of times in worst 10 circuits last 5 years**	**Circuit Ranking (1 = worst)**	**Circuit**	**# of times in worst 10 circuits last 5 years**
1	E6W1	5	**1**	E6W1	5
2	E47X1	2	**2**	E22X1	4
3	E58X1	3	**3**	E21W1	3
4	E22X1	3	**4**	E43X1	4
5	E27X1	2	**5**	E47X1	2
6	E21W1	2	**6**	E51X1	2
7	E43X1	3	**7**	E15X1	2
8	E18X1	2	**8**	E27X1	2
9	E6W2	1	**9**	E21W2	2
10	E51X1	3	**10**	E6W2	1

6.3 System Reliability Improvements (2017 and 2018)

Vegetation management projects completed in 2017 or planned for 2018 that are expected to improve the reliability of the 2017 worst performing circuits are included in table 9 below. Table 10 below details electric system upgrades that are scheduled to be completed in 2018 or were completed in 2017 that were performed to improve system reliability.

Table 9

Vegetation Management Projects on Worst Performing Circuits

Circuit(s)	Year of Completion	Project Description
22X1	2018	Hazard Tree Mitigation
		Mid Cycle Review
58X1	2017	Reliability Analysis
	2018	Planned Cycle Pruning
		Hazard Tree Mitigation
6W1	2018	Hazard Tree Mitigation
		Storm Resiliency Pruning
18X1	2017	Planned Mid Cycle Pruning
		Hazard Tree Mitigation
15X1	2018	Planned Mid Cycle Pruning
		Hazard Tree Mitigation
17W1	2017	Planned Mid-Cycle Review

Table 10

Electric System Improvements Performed to Improve Reliability

Circuit(s)	Year of Completion	Project Description
22X1	2017	Relocation of Mainline
47X1	2017	Circuit 47X1 – Installed Devices and Implement Pulsefinding Scheme
3343 and 3354 Lines	2017	Replaced subtransmission tap switches with motor operated switches and connect to SCADA at Munt Hill Tap, Shaw's Hill Tap, Willow Road Tap, East Kingston substation and New Boston Road Tap
3341, 3352, 3351 and 3362 Lines	2017	Installed in-line motor operated switches with automatic sectionalizing and SCADA control and status in the vicinity of Merrill's Pit
43X1	2018	Replace Willow Road tap recloser and install distribution recloser on Exeter Road
Plaistow Substation	2018	Removal of 4.16 kV Unit transformer switchgear and replace with polemounted steps, regulators and recloser.

7 Tree Related Outages in Past Year (1/1/17 – 12/31/17)

This section summarizes the worst performing circuits by tree related outage during the time period between January 1, 2017 and December 31, 2017.

Table 11 shows the ten worst circuits ranked by the total number of Customer-Minutes of interruption. The number of customer-interruptions and number of outages are also listed in this table.

All streets on the UES-Seacoast system with three or more tree related outages are shown in Table 12 below. The table is sorted by number of outages and customer-minutes of interruption.

Table 11

Worst Performing Circuits – Tree Related Outages

Circuit	Customer-Minutes of Interruption	Number of Customers Interrupted	No, of Interruptions
E22X1	381,327	4,195	7
E6W1	231,999	3,517	18
E58X1	173,361	1,293	12
E47X1	57,895	572	8
E18X1	48,917	610	9
E23X1	44,469	423	9
E13W1	36,052	258	9
E6W2	32,899	282	9
E13W2	28,164	582	14
E19X3	6,099	75	9

Table 12

Multiple Tree Related Outages by Street

Circuit	Street	Town	# Outages	Customer-Minutes of operation	No. of Customer Interruptions
E13W1	North Main St.	Plaistow	4	9,630	66
E6W1	South Rd	E.Kingston / S.Hampton	3	82,373	822
E58X1	Main St	Atkinson	3	40,310	140
E47X1	Hersey Lane	Stratham	3	21,646	145
E27X2	North Road	East Kingston	3	800	9
E21W2	Maple Ave.	Atkinson	3	662	5

8 Failed Equipment

This section is intended to clearly show all equipment failures throughout the study period from January 1, 2017 through December 31, 2017. Chart 3 shows all equipment failures throughout the study period. Chart 4 shows each equipment failure as a percentage of the total failures within this same study period. The number of equipment failures in each of the top four categories of failed equipment for the past five years are shown below in Chart 5.

Chart 3

Equipment Failure Analysis by Cause

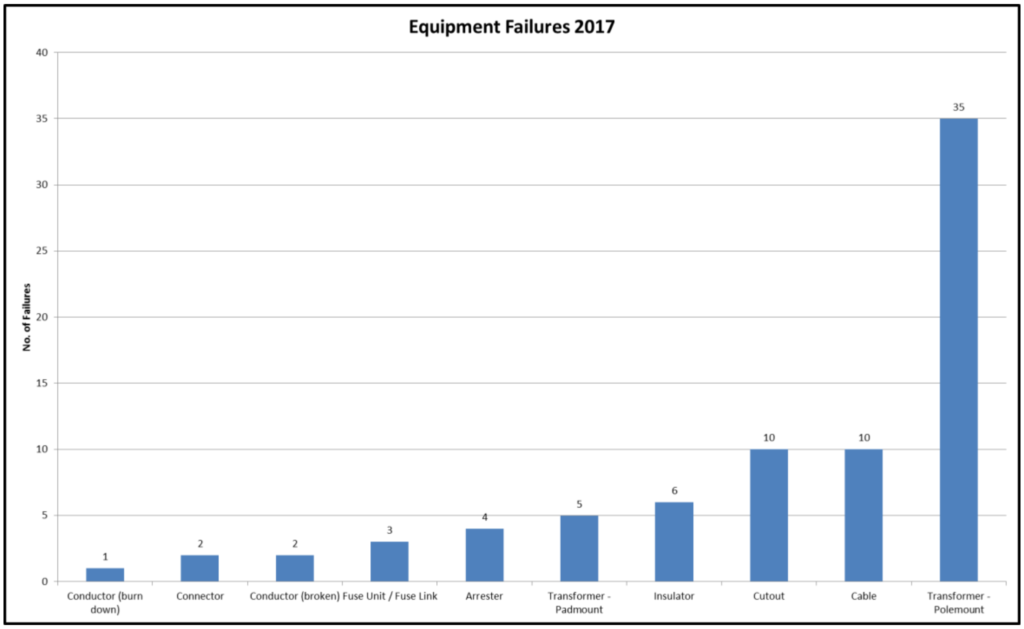


Chart 4

Equipment Failure Analysis by Percentage of Total Failures

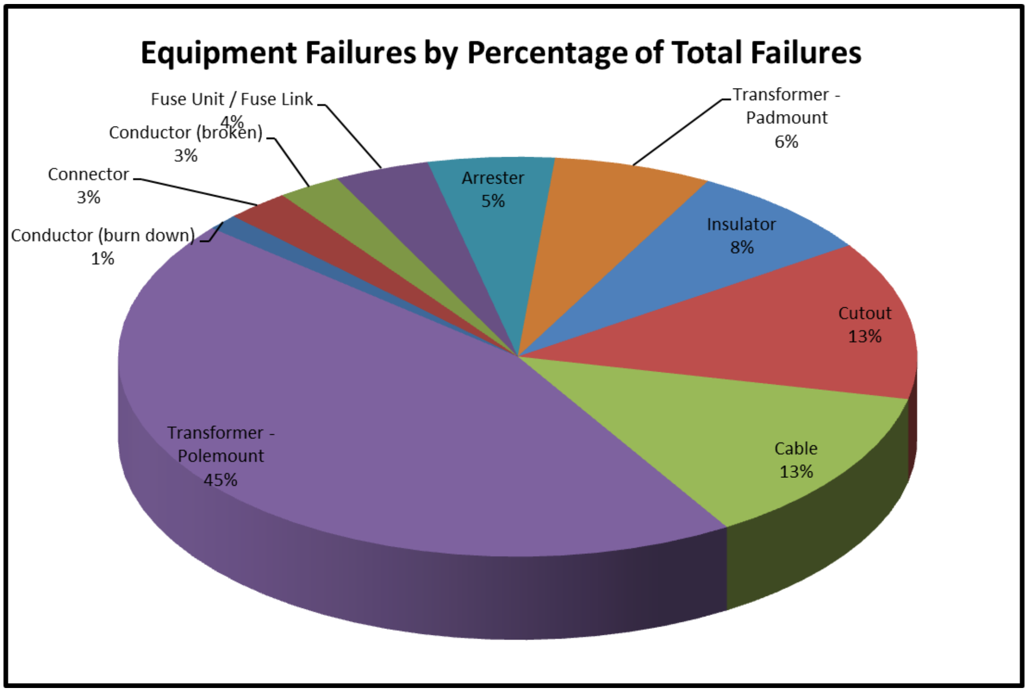
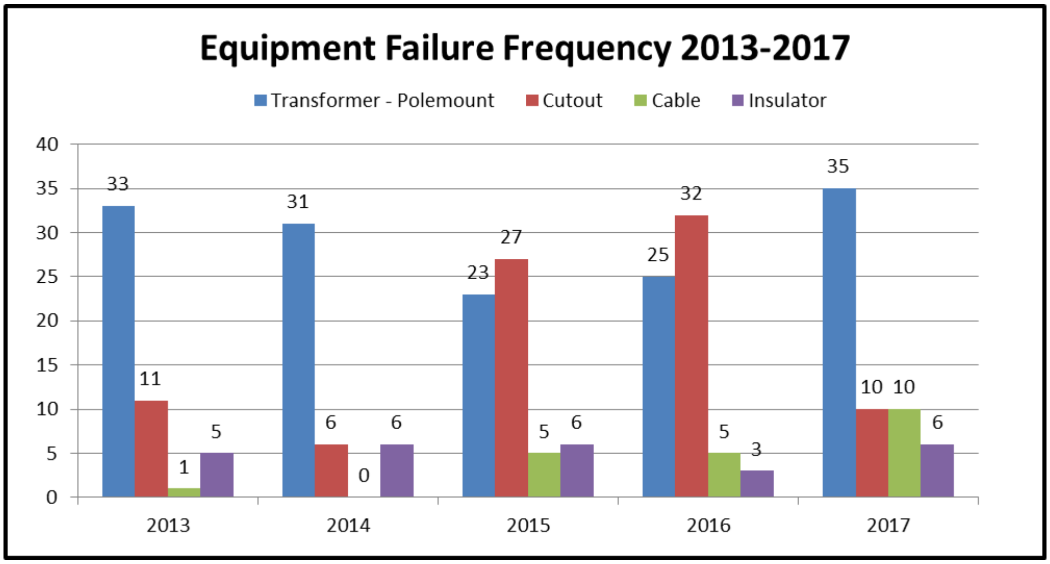


Chart 5

Annual Equipment Failures by Category (top four)



9 Multiple Device Operations in Past Year (1/1/17 – 12/31/17)

A summary of the devices that have operated four or more times from January 1, 2017 to December 31, 2017 are included in table 13 below.

Table 13

Multiple Device Operations

Circuit	Device	Number of Operations	Customer Minutes	Customer - Interruptions
E17W1*	Fuse - Pole 119/92 High St, Hampton	4	93,572	1088
E13W2	Fuse - Pole 19/165 Main St, Newton	4	6,047	60

* The fuse on High St, Hampton at pole 119/92 is scheduled to be replaced with an electronic recloser in 2019.

10 Other Concerns

This section is intended to identify other reliability concerns that would not necessarily be identified from the analysis above.

10.1 Subtransmission Lines across Salt Marsh

The 3348 and 3350 lines are constructed through salt marsh, making them very difficult to access and repair.

In 2017 structure damage caused loss of the 3348 line resulting in outage to circuits 7W1 and 7X2, totaling over 221,000 customer minutes of interruption. In addition the 3348 line was out of service for several months until repairs could be made.

Currently, there is an effort to conduct a detailed assessment of the present condition and evaluate several options for repair, replacement, relocation or elimination of these lines to provide power to the Seabrook area distribution system.

10.2 Vegetation Management

Several streets in Hampton Falls, Kensington and Newton restrict the amount of trimming that can be done due to being classified as scenic roads. This can contribute to the number of tree related outages on several circuits.

Additionally, there are several heavily treed areas where property owners are not willing to allow vegetation trimming aggressive enough to positively impact reliability.

Following are some of the streets with tree trimming refusals:

- Willow Rd, East Kingston
- Depot Rd, Kingston
- High St, Hampton
- Exeter Rd, Hampton Falls
- Burnt Swamp Rd, East Kingston
- Bunker Hill Ave, Stratham

It's recommended to re-conductor these streets and associated side laterals with spacer cable. It may not be practical to complete all of these projects in one year, and some of these are more critical than others. The more critical projects will be detailed Section 11.

11 Recommendations

This following section describes recommendations to improve overall system reliability. The recommendations listed below will be compared to the other proposed reliability projects on a system-wide basis. A cost benefit analysis will determine the priority ranking of projects for the 2019 capital budget. All project costs are shown without general construction overheads.

11.1 Circuit 43X1 - Re-conductor Willow Rd with Spacer Cable

11.1.1 Identified Concerns

Willow Rd had three outages in 2017, two of which were tree related and the other patrolled nothing found. The owner of a section of property along Willow Road from pole 1 to pole 42 near the Willow Road Tap has repeatedly refused to allow effective pruning and hazard tree mitigation. An outage on this is mainline section of 43X1 would affect the majority of the circuit and 1862 customers.

11.1.2 Recommendation

Re-conductor Willow Rd (from Exeter Road pole 1 to Willow Rd pole 42) with spacer cable.

- Estimated Project Cost: $450,000

Customer Exposure = 1,862 customers (.73 miles)

The projected average annual savings for this project is 78,052 customer minutes of interruptions and 950 customer interruptions.

11.2 Circuit 6W1 - Re-conductor Depot Rd with Spacer Cable

11.2.1 Identified Concerns

6W1 has been on the worst performing SAIDI and SAIFI list for the last five consecutive years. 50% of the total customer minutes of interruption occurring since January 2013 were attributable to tree or limb contact with an additional 32% being caused by uprooted or broken tree trunks. The owner of a section of property along Depot Road from pole 41 to pole 50 near the East Kingston Substation getaway has repeatedly refused to allow effective pruning and hazard tree mitigation. An outage on this section of 6W1 would affect the entire circuit (up to 715 customers).

11.2.2 Recommendation

Re-conductor Depot Rd from pole 41 to pole 52 with spacer cable.

- Estimated Project Cost: $175,000

6W1 Customer Exposure = 715 customers (.16 miles)

6W2 Customer Exposure = 939 customers (.1 miles)

The projected average annual savings for this project is 15,098 customer minutes of interruptions and 184 customer interruptions.

11.3 Circuit 13W1 - Install Fusesaver on Culver St

11.3.1 Identified Concerns

The fuses on pole 1 Culver St operated three times in 2017. Two of the operations were recorded as patrolled with nothing found.

11.3.2 Recommendation 1

Install a Siemens Fusesaver at pole 1 Culver St.

- Estimated Project Cost: $9,000

Customer Exposure = 111 customers (1.8 mi.)

The projected average annual savings for this project is 2,840 customer minutes of interruptions and 35 customer interruptions.

11.4 Circuit 19X2 – Distribution Automation Scheme with Portsmouth Ave

11.4.1 Identified Concerns

On average one subtransmission outage per year causes an outage to Portsmouth Ave substation or Gilman Lane substation.

Additionally, Portsmouth Ave substation is supplied from the 3347 line, which is a radial line that typically experiences damage during major events.

11.4.2 Recommendation

This project will consist of replacing the 11X2J19X2 tie switch with a recloser and the installation communication infrastructure between the new recloser, the 19X2 recloser at Gilman Lane substation and Portsmouth Ave substation.

A distribution automation scheme will be implemented that will restore the 1,700 customers on circuits 11X1 and 11X2 via circuit 19X2 for the loss of the 3347 line. Additionally, for a fault on the 3352 line or 3362 line the 600 customers supplied by circuit 19X2 will automatically be restored via circuit 11X2.

- Estimated annual customer-minutes savings = 81,473
- Estimated annual customer-interruption savings = 992

Estimated Project Cost: $200,000

11.5 Circuit 17W1 – Install Hydraulic Reclosers and Sectionalizer

11.5.1 Identified Concerns

17W1 was one of the worst performing circuits in 2017.There is an approximately one mile section of North Shore Rd that is heavily wooded with only one sectionalizing point.

11.5.2 Recommendation

Add two single phase reclosers on North Shore Rd pole 35, replace 125 QA fusing at pole 18 with cutout mounted sectionalizer and install fused cutouts at pole 11.

- Estimated Project Cost: $30,000

Add recloser pole 35

Customer Exposure = 174 customers (.95 miles)

Add cutout mounted sectionalizer pole 18

Customer Exposure = 40 customers (.57 miles)

Add fuse pole 11

Customer Exposure = 27 customers (.36 miles)

The projected average annual savings for this project is 5,153 customer minutes of interruptions and 63 customer interruptions.

11.6 Miscellaneous Improvements to Reduce Recurring Outages

The following concerns were identified based on a review of Tables 12 (Multiple Tree Related Outages by Street) and 13 (Multiple Device Operations) of this report as well as the failed equipment section.

11.6.1 Mid-Cycle Forestry Reviews

The areas identified below experienced three or more tree related outages in 2017. It is recommended that a forestry review of the following areas be performed in 2019 in order to identify and address any mid-cycle growth or hazard tree problems.

- 13W1, North Main St, Plaistow
- 6W1, South Rd, E.Kingston / S.Hampton
- 58X1, Main St, Atkinson
- 47X1, Hersey Ln, Stratham
- 27X2, North Rd, E.Kingston
- 21W2, Maple Ave, Atkinson

11.6.2 Wildlife Protection Reviews

The areas identified below experienced two or more animal related outages in 2017. It is recommended that the wildlife protection in the following areas be reviewed in 2019 in order to identify and address any missing or inadequate animal guarding.

- 6W2, Rockrimmon Rd., Kingston
- 6W2, Main St, Kingston
- 11X1, Trish's Way, Stratham
- 21W2, West Side Dr, Atkinson

11.6.3 Cutout Failures

Cutout failure rates have had a notable increase since 2013, and all of the failures have all occurred on the older vintage ceramic cutouts. UES-Seacoast has implemented more aggressive replacement policy when cutouts fail. When one cutout fails out of a three-phase set and causes an outage, all three cutouts will be replaced if they are the same vintage. Unitil has also performed analysis to find circuits with the highest rate of failures. Associating this information with the number of customers on each circuit, a circuit priority list for cutout replacements was created. Using this list, operations has started to replace mainline ceramic cutouts on the more critical circuits.

12 Conclusion

The UES-Seacoast system has been affected by outages involving tree contact and equipment failures. A more aggressive tree trimming program began in 2011 and has started to reduce the number and impact of tree related outages. 2017 was the best year in terms of SAIDI and SAIFI since the program started in 2011.

In 2012 three circuits on the UES-Seacoast benefited from a storm resiliency pruning (SRP) pilot, which consisted of ground to sky trimming and hazard tree removal. Due to the success of this pilot, five additional UES-Seacoast circuits had SRP performed in 2014 and an additional six circuits were completed in 2016. Additionally, six circuits are expected to be completed in 2018. In areas where aggressive tree work is not possible, alternative solutions are being sought in order to minimize outages caused by tree related damage.

The recommendations in this report are aimed at reducing the duration and customer impact of outages by increasing system flexibility for quicker restoration of customers, addition of isolation points at effective locations and replacing conductors with more resilient cabling systems in strategic locations. This report is also intended to assist Unitil Forestry in identifying areas of the system that are being frequently affected by tree related outages to allow proactive measures to be taken.

Attachment 4

Reliability Project Listing

2018 Budget Versus Actual Expenditures

Reliability Project Listing
2018 Budget Versus Actual Expenditures
UES Capital

DOC	Bud #	Description	Auth #	Budgeted	Authorized	Actual Exp.	Comment
UES Capital	DPBC01	Condemned Poles Distribution	180113	$779,539.57	$858,995.57	$864,294.94	Complete
UES Capital	DRB00	2018 Reliability Project Budget		$392,902		$123,203	
UES Capital	DRBC10	Circuit 18W2: Install Recloser	180153	$90,831.62	$126,000.00	$48,976.98	Complete
UES Capital	DRBC02	Bridge Street Substation Reliability Enhancements		$171,820.38			Project was replaced with West Concord enhancements (below)
UES Capital	DRBC12	West Concord Substation Reliability Enhancements	180163		$108,754.00	$74,226.38	Complete
UES Capital		2017 Reliability Projects Carry Over to 2018					
UES Capital	DROC15	Install 430 ft of conduit and 1/0 Al 35KV URD Cable	170155		$53,829.36	$59,298.95	Complete
UES Capital	DROC13	Substation Reliability Improvements at Penacook	170166		$172,000.00	$202,478.50	Complete

Reliability Project Listing
2018 Budget Versus Actual Expenditures
UES Seacoast

DOC	Bud #	Description	Auth #	Budgeted	Authorized	Actual Exp.	Comment
UES Seacoast	DPCE01	Distribution Pole Replacements	181009	$754,901.37	$754,901.37	$638,733.86	Active
UES Seacoast	DRB00	2018 Total Reliability Budget		$461,706		$500,765	
UES Seacoast	DRBE01	Installation of Recloser, Exeter Rd., Kingston - Circuit 43X1	181028	$215,262.80	$175,000.00	$213,676.55	Complete
UES Seacoast	DRBE07	3346 Line - Automatic Restoration Scheme	181030	$161,216.99	$570,000	$121,971.45	2 Year project. Auth $ is full Project to be complete in 2019
UES Seacoast	DRBE16	Guinea Switching Reliability Enhancements	181046	$85,226.21	$188,000.00	$165,117.04	Active
UES Seacoast		2017 Reliability Projects Carry Over to 2018					
UES Seacoast	DROE01	Install Devices with Pulse Finding	171020	$413,510.25	$413,510.25	$450,529.11	Compete